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(54) Title: AN OPTICAL NETWORK WITH PROTECTION PATH FOR FAILURE RECOVERY

(57) Abstract

An optical communication network for distribution of light signals and comprising a working and a protection path optical fiber for propagation of light signals. A part of a first light signal is coupled into the working path optical fiber and a copy of the first light signal is selectively coupled into the protection path optical fiber. The network further comprising an optical switch and control means for controlling the optical network in such a way that a first output of the optical switch is connected to a first input in a first switch position unless light signals can not be received by a first light receiver with the switch in its first switch position in which case the switch is controlled to switch to a second switch position connecting the first output to a second input of the optical switch and coupling the copy of the first light signal into the protection path optical fiber.

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AN OPTICAL NETWORK WITH PROTECTION PATH FOR FAILURE RECOVERY

FIELD OF THE INVENTION

The present invention relates to an optical network utilizing a simple failure recovery technique.

BACKGROUND OF THE INVENTION

It is well known to distribute information optically through optical fibers capable of distributing information digitally at very high bit rates.

In a telecommunications network, optical fibers are typically utilized at the trunk level, i.e. the level at which a large amount of information from many sources and destinated to many users are packed together for distribution on a trunk line, e.g. between two large cities. The information may comprise any kind of digitized information, such as speech exchanged over telephones, radio, television, computer data, etc.

Typically, an optical trunk network distributes data between high density population areas and comprises nodes positioned in the area and having optical receivers converting the received optical signals to electrical signals and an electrical switching network distributing the data received to the intended receivers throughout the area or to other trunk nodes.

Various electrical and optical network topologies are known and the most commonly used are

the ring network that is a closed structure in which each node is connected to two other nodes in the ring so that information may be passed between nodes in two directions,

the quadratic or meshed network in which each node is connected to four other nodes in the network, and

the hubbed network in which each node is connected to one node (the hub) receiving and generating large amounts of information.

Electrical networks for transmission and distribution of information typically comprise a large number of matrix switches enabling a large number of inputs to be selectively interconnected with a large number of outputs, respectively, whereby a large number of nodes in the network may be interconnected with each other. Fault tolerant systems may be provided this way as several data transmission paths may exist between two nodes in the network and thus, if an error occurs in one transmission path, an alternative transmission path may be established relatively quickly.

In the art, two requirements for an electrical network or an optical network having optical switches are considered important: the network must provide provisioning and restoration.

Provisioning is dynamic establishment of an interconnection for data transfer of a specific data rate between two selected nodes in the network.

Restoration is dynamic establishment of an alternative interconnection between two selected nodes in the network upon erroneous disconnection of a first interconnection, e.g. caused by a cable cut.

As optical switches with several inputs and several outputs are extremely expensive, optical networks in which data can be switched without converting optical signals to electrical signals before switching and vice versa after switching are not considered to be commercially feasible in the art.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an optical network with optical switches that is commercially feasible.

It is another object of the present invention to provide an optical network with restoration capability.

It is a further object of the present invention to provide an optical trunk network with optical switches that is simple.

It is yet another object of the present invention to provide a wavelength division multiplexed optical network with optical switches that is simple.

According to the invention the above and other objects are fulfilled by an optical communication network for distribution of light signals comprising:

a first light source for emission of a first light signal,

a working path optical fiber for propagation of light signals,

a first optical coupling means for coupling a part of the first light signal into the working path optical fiber,

a protection path optical fiber for propagation of light signals,

a second optical coupling means for selectively coupling a copy of the first light signal into the protection path optical fiber,

a first optical switch for switching optical signals and having

a first input that is optically connected to the working path optical fiber,

a second input that is optically connected to the protection path optical fiber,

a first output that is selectively connected to either the first input or the second input, and

a second output that is selectively connected to the input that is not connected to the first output,

a first light receiver for reception of light signals and being optically connected to the first output of the first optical switch,

a second light receiver for reception of light signals and being optically connected to the second output of the first optical switch,

control means for controlling the optical network in such a way that

the first output of the first optical switch is connected to the first input in a first switch position unless light signals can not be received by the first light receiver with the switch in its first switch position in which case the switch is controlled to switch to a second switch position connecting the first output to the second input and

the second optical coupling means are controlled to couple the copy of the first light signal into the protection path optical fiber.

The optical network may constitute a trunk network, preferably operating at data rates at the Gbit/s level, and preferably above 0.5 Gbit/s, more preferred at or above 1 Gbit/s, still more preferred at or above 2 Gbit/s and even more preferred at or above 2.5 Gbit/s and most preferred at or above 10 Gbit/s.

Data organized as Synchronous Digital Hierarchy (SDH) data, Asynchronous Transfer Mode (ATM) data, etc, may be distributed in the optical network.

According to a first important aspect of the present invention, automatic provisioning is not a feature of the provided optical network. The inventor has been first to recognize that automatic provisioning is not a necessary feature in optical trunk networks operating in the Gbit/s data rate range. The need for high data rate interconnections between nodes, such as cities or countries, are determined by population density, economic activity, etc, parameters that do not change at a rate that require automatic equipment to be coped with. If the required data rate to or from a node increases, it will be convenient and economically feasible to manually connect more fiber optic links to the node in question.

According to a second important aspect of the present invention, restoration is provided in a simple way. The information to be transferred from a first node in the network to a second node in the network may always propagate through two different optical fibers. For example, the light emitted from the first light source at the first node may be divided into a first and a second light signal by an optical directional coupler, e.g. a 3 dB directional coupler, the first light signal being coupled into the working path fiber for propagation to the second node and the second light signal being coupled into the protection path fiber also for propagation to the second node. In its first and initial switch position, data from the working path fiber is

transferred to the first receiver. If an error occurs, e.g. the working path fiber is cut, the switch changes position so that the first receiver is connected to the protection path fiber whereby the data transmission path between the first and the second node is restored.

In stead of coupling light from the first light source into both the working path fiber and the protection path fiber, a second light source may be used to emit a second light signal that is a copy of the first light signal, i.e. the first and the second light signal contain the same information, and that is coupled into the protection path fiber. Thereby, an error in the first light source may be recovered by the network by switching the first optical switch to its second switch position.

It is an advantage of the two above-mentioned optical networks that data may be propagated continuously through the protection path fiber providing continuous verification of correct operation of the protection path.

The control means of the network may comprise a local node controller comprising a processor that is electrically connected to a selector input of the first optical switch for selection of its switch position. The processor may further be electrically connected to the first light receiver for detection of reception of light signals at the light receiver and may be adapted to switch the first optical switch from its first switch position to its second switch position upon detection of loss of signal at the first light receiver.

Loss of signal or signal degradation may be detected by simple signal power determination, detection of lack of synchronization, bit error rate detection, etc, or any combination hereof.

A plurality of working paths between the first and the second node may share a common protection path. For example, two working paths may share a common protection path. An optical switch at one end of the shared protection path fiber may be used to switch the fiber end between the two light sources of the working paths and another optical switch at the other end of the protection path fiber may be used to switch the fiber end between the two receivers of the working paths, respectively.

Preferably, data are propagated substantially continuously through the shared protection path fiber alternatingly originating from the two light sources of the two respective working paths whereby substantial continuous verification of the ability of the shared protection path to substitute either of both working paths is provided.

In a network with a shared protection path, the second optical coupling means is preferably a second optical switch having a first input that is optically connected to the first light source or another light source for emission of a light signal containing the same information as the light signal intended to be emitted by the first light source, a second input that is optically connected to a second light source for emission of a second light signal, and a first output that is selectively connected to either the first input or the second input. The control means may further be adapted to control the second optical switch in such a way that the first output of the second optical switch is connected to the first input when light signals can not be received by the first light receiver with the first optical switch in its first switch position. If, for example, the control means comprise a local node controller, the controller may be connected to a selector input of the second optical switch for selection of its switch position and be adapted to control the switch as described.

It is an advantage of the optical network according to the present invention that it comprises simple components only.

It is another advantage of the optical network according to the present invention that protection paths are monitored regularly for its ability to substitute the corresponding working paths.

It is yet another advantage of the optical network according to the present invention that the restoration method and means employed are simple.

It is still yet another advantage of the optical network according to the present invention that the restoration method and means may be employed in a point to point communication line or in any network regardless of its topology, such as a ring network, a meshed network, a hubbed network, etc.

It is a further advantage of the optical network according to the present invention that upon occurrence of an error in a working path, information is quickly routed to the protection path, e.g. controlled by a local node control system, without involving network management.

It is a still further advantage of the optical network according to the present invention that the time needed for the network to recover after occurrence of an error is very short thus, minimizing data loss.

The optical network may be a wavelength division multiplexed network comprising light sources emitting light of different wavelengths. A plurality of light signals of different wavelengths may simultaneously propagate through each optical fiber in the network. At the receivers the light signals are optically de-multiplexed according to their respective wavelengths so that each receiver receives light of a single wavelength.

It is an advantage of a wavelength division multiplexed network according to the present invention that only a relatively small number of optical transmitters and receivers are needed at each node in the network. Information for another node in the network is routed optically and thus, only receivers and transmitter for information originating from or destinated to the node in question are needed at the node. In a conventional network, all information at a node has to be converted to electrical signals for electrical routing and converted back to optical signals after routing.

It is another advantage of a wavelength division multiplexed network according to the present invention that optical receivers and transmitters at a node in the network are required to operate at relatively low bit rates compared to conventional networks as only the fraction of the information destinated for or originating from the node has to be converted from optical signals to electrical signals or vice versa.

It is a further advantage of a wavelength division multiplexed network according to the present invention that a low number of repeaters are needed as several wavelengths may share the same optical repeater.

It is yet another advantage of a wavelength division multiplexed network according to the present invention that compared to a time division multiplexed network fewer dispersion compensating fibers are necessary leading to savings in optical power and cost.

The invention will now be described by way of example and with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 shows a cost comparison between a wavelength division multiplexed network and a TDM network,

Fig. 2 shows schematically four different cost saving features,

Fig. 3 shows diagrammatically a TDM network and wavelength division multiplexed network,

Fig. 4 shows schematically a part of a protection and restoration network,

Fig. 5 shows four different implementations of protection and restoration networks,

Fig. 6 is a table showing the cost of protection and restoration for different networks,

Fig. 7 schematically shows a network node,

Fig. 8 shows schematically a meshed network with shared protection.

DETAILED DESCRIPTION OF THE DRAWINGS

For comparison a wavelength division multiplexed (WDM) optical network and a present TDM network is schematically shown in Fig. 1. A WDM network 11 with four links each carrying 2.5 Gbit/s and a TDM network 13 with one link 14 carrying 10 Gbit/s are shown. The networks 11, 13 are point to point networks. In order to compare the costs of these two networks an old thumb-rule is used saying that a four-fold increase in the bit rate only increases the cost by a factor of 2.5. Thus, the 10 Gbit/s transmitter/receiver 15 will cost 2.5 times the cost of one of the 2.5 Gbit/s transmitter/receivers 16. In the example shown in Fig. 1, this means that the WDM network 11 with four 2.5 Gbit/s transmitter/receivers 16 will cost 4 units whereas the TDM network 13 using one 10 Gbit/s transmitter/receiver 15 will cost 2.5 units, the cost of one 2.5 Gbit/s transmitter/receiver constituting a unit.

Thus, WDM is not cost effective point-to-point systems.

When discussing the costs of an optical network there are basically four ways of saving costs. Examples of cost saving features are shown in Fig. 2.

Fig. 2a shows saving in bandwidth or in transmitter/receivers. In Fig. 2a a fiber carrying four signals at each different wavelengths 20, 21, 22, 23 are arriving at a node, each wavelength carrying 2,5 Gbit/s. In standard TDM network 25, all four signals 20, 21, 22, 23 will be received in a 10 Gbit/s transmitter/receiver 24. In WDM optical network 26 only a fraction of the electrical bandwidth is needed as only the bandwidth of the datapart to be actually received at the node is necessary. At the node 27, only the data at wavelength 22 is received and thus, only a 2,5 Gbit/s transmitter/receiver 27 is needed. This saves transmitter/receiver bandwidth compared to the network 25 where all wavelengths are transmitted through a 10 Gbit/s transmitter/receiver 24 and the network 26 therefore saves costs as optoelectronic converters at a lower bit rate are less expensive than the optoelectronic converters at a higher bit rate.

Fig. 2b shows a network 34 with shared repeaters, where four signals at each different wavelengths share one repeater 28 which save costs compared to the network 35 where a repeater 28 with a bandwidth large enough to receive all four signals is needed.

Fig. 2c shows a routing WDM network 30 where signals 29 are routed without being actually received at the node 31 . This is a clear advantage to the standard network 32 where all signals are received at 10 Gbit/s transmitter/receivers 24 and then redirected through other 10 Gbit/s transmitter/receivers 24.

Due to the lower bit-rates of the WDM network fewer dispersion-compensating fibers 33 are necessary as shown in Fig. 2d. Therefore optical power as well as the fairly expensive dispersion compensating fibers 33 are saved.

In Fig. 3 a simple diagram illustrates a TDM network 130 and a WDM network 120 for comparison. In Fig. 3a the demand for bandwidth is shown. As can be seen 2,5 Gbit/s is needed between node A and node B, 2,5 Gbit/s is needed between node A and node C, 2,5 Gbit/s is needed between node C and node D, and finally 5 Gbit/s is needed between node A and node D.

In Fig. 3c a typical TDM 130 realisation is shown schematically. From node A to node B is only one path 131 including two fibers for two way transmission. A 10 Gbit/s transmitter/receiver 132 at node A transmits 10 Gbit/s to a 10 Gbit/s transmitter/receiver 133 at node B, from node B a 10 Gbit/s transmitter/receiver 134 transmits the remaining 7,5 Gbit/s to a 10 Gbit/s transmitter/receiver 135 at node C. From a 10 Gbit/s transmitter/receiver 136 at node C the remaining 5 Gbit/s plus the new 2,5 Gbit/s is transmitted to a 10 Gbit/s transmitter/receiver 137 at node D. This network comprises six 10 Gbit/s transmitter/receivers.

From the WDM realisation shown diagrammatically at Fig. 3b, it is seen that at node A four 2,5 Gbit/s transmitter/receivers 138, 139, 140, 141 are placed. The first 2,5 Gbit/s transmitter/receiver 138 transmits 2,5 Gbit/s to the transmitter/receiver 142 placed at node C. The second and fourth 2,5 Gbit/s transmitter/receivers 139, 141 transmits 5 Gbit/s to two 2,5 Gbit/s transmitter/receivers 143, 144 at node D. The third 2,5 Gbit/s transmitter/receiver 140 transmits 2,5 Gbit/s to the 2,5 Gbit/s transmitter/receiver 145 at node B. At last the 2,5 Gbit/s transmitter/receiver 146 at node C transmits 2,5 Gbit/s to 2,5 Gbit/s transmitter/receiver 147 at node D. This network comprises ten 2,5 Gbit/s transmitter/receivers.

Using the previously defined cost-unit of 2,5 Gbit/s, the cost of the TDM network is 6 x 2,5 = 15 cost-units, whereas the cost of the corresponding WDM network is only 10 cost-units. To keep the WDM at a lower cost than the TDM network, the cost of all extra necessities, such as optical multiplexers, optical de-multiplexers and optical cross-connects, for the WDM network must be kept lower than 5 cost-units. In this simple example there are four nodes in the network so each cross-connect must cost below 5/4 cost-units.

Further, the cost of protection and restoration, so as to provide recovery in case of e.g. a fiber cut, must not exceed the corresponding cost of TDM networks. Network recovery capability is becoming increasingly more important as still more information is transmitted by the networks and therefore the consequences of a transmitter/receiver breakdown or a fiber cut are becoming more and more severe.

In Fig. 4a a network interconnection with protection between two network nodes is shown. A transmitter 42, receivers 43, 47 and the connections 44, 45 therebetween are shown schematically. The transmitter signal propagates via two paths 44, 45, one working 44 and one protection 45, to the receivers 43, 47. In front of the receiver, an optical switch 46 determines which signal is received at the first receiver 43. The signal that is not received at the first receiver 43 is coupled to a protection receiver 47 which checks the protection signal. In Fig. 4b a protection path 45 is shared by different working paths 44, 48. In Fig. 4c, a protection check receiver 47 which receives and checks signals from several protection paths 49 is shown. The protection check receiver 47 receives and checks signals from path 1 to path 5 49, respectively through 1xN optical switch 50.

In Fig. 5 four ways of providing protection and restoration in networks 51, 52, 53, 54 are illustrated. Fig. 5a shows schematically a simple network with only link protection comprising one transmitter/receiver 55 and an optical switch

56 for coupling part of the optical signal to working path 44 and another part of the signal to protection path 45. This protection method is cheap, the transmitter/receiver 55 is, however, not protected and can not be automatically replaced in case of failure.

Fig. 5b illustrates a transmitter protection network 52 comprising a transmitter/receiver 55 for the working path 44 as well as for the protection path 45. This provides protection and restoration in case of a transmitter/receiver failure, the use of the bandwidth is however inefficient and with a transmitter/receiver 55 for each working path 44 and a transmitter/receiver for each protection path 45 the design is not very cost-effective.

In Fig. 5c a shared transmitter protection network 53 is shown schematically. Here, the transmitter uses half the bandwidth of a neighbouring transmitter and therefore uses the bandwidth more efficient. This resembles the Multiplex Section Selfhealing Protection Ring (the MSSPring) principle.

The most promising protection network is illustrated in Fig. 5d, wherein transmitter/receiver 55 protection and link failure protection is provided. In this protection network n working paths 44 with each a transmitter/receiver 55 share 1 or m protection paths 45 with 1 or m protection transmitter/receivers 55, so as to provide a n:1 or n:m transmitter and path protection network.

Fig. 6 shows a table of the extra cost associated with protection and restoration. The extra cost for the four different ways of providing protection and restoration in WDM networks shown in Fig. 5 and for different TDM networks are shown. The cost of protection and restoration may be estimated by counting of transmitter/receivers 55 used in the network. The table in Fig. 6 shows the protection and restoration cost for the four types of WDM network 51, 52, 53, 54 (shown in Fig. 5). Further the extra cost for

different TDM networks: MSSPring 67, restoration 68, and 1+1 or 1:1 69 networks are shown. The network type is noted in the column 61 and in column 62 it is noted whether the transmitter is protected or only the path is protected. In the column 63 the extra cost for having the network protected (C_{prot}) 64 is calculated. In the upper half of the table 65 it is calculated for WDM networks and in the lower half 66 for TDM networks. The factor K_t is a factor indicating that the cost per bit is lower if the bit rate is increased (compare with the mentioned thumb-rule), and where d is the network node connectivity degree (i.e., number of outgoing cables from the node). The extra cost factor, C_{prot}, is to be multiplied with the cost of the network without protection (where cost here is the number of transmitter/receiver).

For the WDM networks cost are as the following: for the link protection 51 the cost is low, less than 1,05 cost-units, the only extra cost being a low-cost optical switch but at the expense of a non-protected transmitter. The network 52 has full transmitter protection and full link protection, but at the cost of 2 cost-units, because of the extra protection transmitter used for each working transmitter. The network 53 has shared transmitter protection and the cost is therefore 2^{1+Kt} cost-units plus the cost of electrical cross-connects, The factor K_t indicating that the bandwidth is used more efficient. The network 54 with n:1 or n:m transmitter protection has an extra cost for protection of only 1 + m/n cost-units plus extra cost for optical cross-connectors, where n is the number of nodes in the network and m is the number of transmitters protected.

For comparison the cost for protection and restoration in a TDM network is shown in the lower half of the table. It is seen that the cost for MSSPring protection is 2^{1+Kt} cost-units. The cost for protection and restoration in a TDM network is $(1 + 1/d)^{1+Kt}$ cost-units and the cost for 1 + 1 or 1:1 protection is 2 cost-units.

It is to be noted that when considering the cost involved in the protection and restoration mechanism, the number of transmitters/receivers are counted. When modelling a higher bit-rate, the simple thumb-rule of quadrupling the bit rate is generalised. Say, if 1 2.5 Gbit/s transmitter/receiver cost 1, a 10 Gbit/s transmitter/receiver costs 2.5. E.g., per bit does the 10 Gbit/s transmitter/receiver cost 2.5/4 = 0.625. This can be generalised in the formula cost per bit = (increase in bit rate)^{Kt}, where K_t = -0.339 for in the typical case and otherwise between -0.2 to -0.7. For 10 Gbit/s, the cost per bit is $(4)^{-0.339}$ = 0.625, for an imagined 40 Gbit/s transmitter/receiver, it would be 0.625*2.5/4 = 0.39 or just $(16)^{Kt} = (16)^{-0.339}$ = 0.39.

Comparing the cost of protection and restoration for TDM and WDM networks it can be seen that especially the protection and restoration network 54 shown in Fig. 5d has potentially a very low cost even compared with the restoration typically used in TDM, which is effective though difficult to realise.

In Fig. 7 an optical node design according to the invention is shown. This implementation shows one optical node 71 for use in a meshed network. The node comprises incoming fibers 72, optical de-multiplexers 73, an optical connection field 74, a switch array for shared protection 75, a 1:N protection path receiver 76, an electrical 1:N MSP which includes a transmitter/receiver 78 for each wavelength used in node 71 and a protection transmitter/receiver 79, a 2x2 switch 80 and a splitter 81 for each wavelength, optical multiplexers 82 for multiplexing the signals, and optical fibers 83 out of the node.

The signals at the incoming fibers 72 are de-multiplexed in the de-multiplexers 73, they then propagate to the optical connection field 74, which may be manual. The optical connection field 74 is set up by the operator to direct the signals according to set-up of a local network.

The protection signals not to be received are directed to the switch array 75 where they are switched or splitted (see description of Fig. 10) whereafter they are directed back to the optical connection field 74 and directed to the optical multiplexers 82, where they are multiplexed and send to the outgoing fibers 83.

The working and protection signals to be received at the node 71 are directed through the optical connection field 74 to the optical switches 80. The switches 80 are controlled so as to receive the working signals in the receiver 78, and direct the protection signal through the protection path check-switch 76 to be received at the shared receiver 79. At the shared receiver 79 one signal is checked at a time due to the insertion of the 1xN switch 76.

If at one of the working receivers 78 no signal is received, the corresponding switch 80 are controlled to be switched so that the protection signal is received at the working receiver 78.

The light sources or transmitters 78 emit signals to be transmitted to the next node. The signal is split in a working and a protection signal by the 1x2 switches or splitters 81 and is via bus 84, which is a collection of fibers, send to the optical multiplexers 82 and further directed to each of the fibers 83 leaving the node

If a transmitter 78 fails, a protection transmitter 79 takes over and emits the signal which is directed to the optical multiplexers 82 like a standard non-transmitter-protected signal.

Obviously there are many variations of how a node can be implemented, comprising using integrated optical switches, or replacing the 1:N MSP with one 1:1 system, terminal multiplexers and a digital cross-connect. The system may

further be optimised in other ways with respect to optical loss.

In Fig. 8 is shown a meshed network 90 with shared protection and six nodes A, B, C, D, E, and F. Only one wavelength is indicated. The path 95 between node A and node D and the path 96 between node C and F are working paths, the path between node B and node A 91, between node B and node C 92, between node D and node E 94, and between node E and node F 93 are dedicated protection paths whereas the path 97 between node B and node E is shared. If a signal arriving at node B is directed towards node E to be send to node D and node F, the signal is send through switch 98 and further through the splitter 99 to split the signal. This is done in order to keep a constant optical power level at each link (except when switching).

CLAIMS

1. An optical communication network for distribution of light signals and comprising

a first light source for emission of a first light signal,

a working path optical fiber for propagation of light signals,

a first optical coupling means for coupling a part of the first light signal into the working path optical fiber,

a protection path optical fiber for propagation of light signals,

a second optical coupling means for selectively coupling a copy of the first light signal into the protection path optical fiber,

a first optical switch for switching optical signals and having

a first input that is optically connected to the working path optical fiber,

a second input that is optically connected to the protection path optical fiber,

a first output that is selectively connected to either the first input or the second input, and

a second output that is selectively connected to the input that is not connected to the first output,

a first light receiver for reception of light signals and being optically connected to the first output of the first optical switch,

a second light receiver for reception of light signals and being optically connected to the second output of the first optical switch,

control means for controlling the optical network in such a way that

the first output of the first optical switch is connected to the first input in a first switch position unless light signals can not be received by the first light receiver with the switch in its first switch position in which case the switch is controlled to switch to a second switch position connecting the first output to the second input and

the second optical coupling means are controlled to couple the copy of the first light signal into the protection path optical fiber.

2. A system according to claim 1, wherein the copy of the first light signal is a part of the first light signal.

3. A system according to claim 1 or 2, wherein the second optical coupling means is a second optical switch having

a first input that is optically connected to the first light source,

a second input that is optically connected to a second light source for emission of a second light signal, and

a first output that is selectively connected to either the first input or the second input, and wherein

the control means is further adapted to control the second optical switch in such a way that the first output of the second optical switch is connected to the first input when

light signals can not be received by the first light receiver with the first optical switch in its first switch position.

4. A wavelength division multiplexed optical communication network according to any of the preceding claims, further comprising

a plurality of light sources for emission of light signals, each of the light sources being adapted to emit light at a specific wavelength that is different from the wavelengths of light emitted from the other light sources, and wherein

the first optical coupling means are further adapted to simultaneously couple parts of the light signals into the working path optical fiber, and

the second optical coupling means are further adapted to simultaneously couple a copy of the light signals into the protection path optical fiber, and further comprising

optical separation means for separating light signals from the first or second outputs of the first optical switch into separate light signals, each having a specific wavelength,

a plurality of first light receivers for reception of light signals of specific wavelengths, respectively, and being optically connected to the first output of the first optical switch,

a plurality of second light receivers for reception of light signals of specific wavelengths, respectively, and being optically connected to the second output of the first optical switch.

5. A method for distribution of light signals in an optical communication network and comprising the steps of

interconnecting a first node of the network and a second node of the network with a working path optical fiber for propagation of light signals,

interconnecting the first node of the network and the second node of the network with a protection path optical fiber for propagation of light signals,

interconnecting a first light receiver for reception of light signals and a second light receiver for reception of light signals with the working path fiber and the protection path fiber, respectively, through a first optical switch for switching optical signals and having a first input, a second input, a first output that is selectively connected to either the first input or the second input, and a second output that is selectively connected to the input that is not connected to the first output, in such a way that the first input is optically connected to the working path optical fiber, the second input is optically connected to the protection path optical fiber, the first receiver is optically connected to the first output, and the second receiver is optically connected to the second output,

emission of a first light signal from a first light source,

coupling a part of the first light signal into the working path optical fiber with a first optical coupling means,

selectively coupling a copy of the first light signal into the protection path optical fiber with a second optical coupling means,

controlling the optical network in such a way that

the first output of the first optical switch is connected to the first input in a first switch position unless light signals can not be received by the first light receiver with the switch in its first switch position in which case the switch is controlled to switch to a second switch position connecting the first output to the second input and

the second optical coupling means are controlled to couple the copy of the first light signal into the protection path optical fiber.

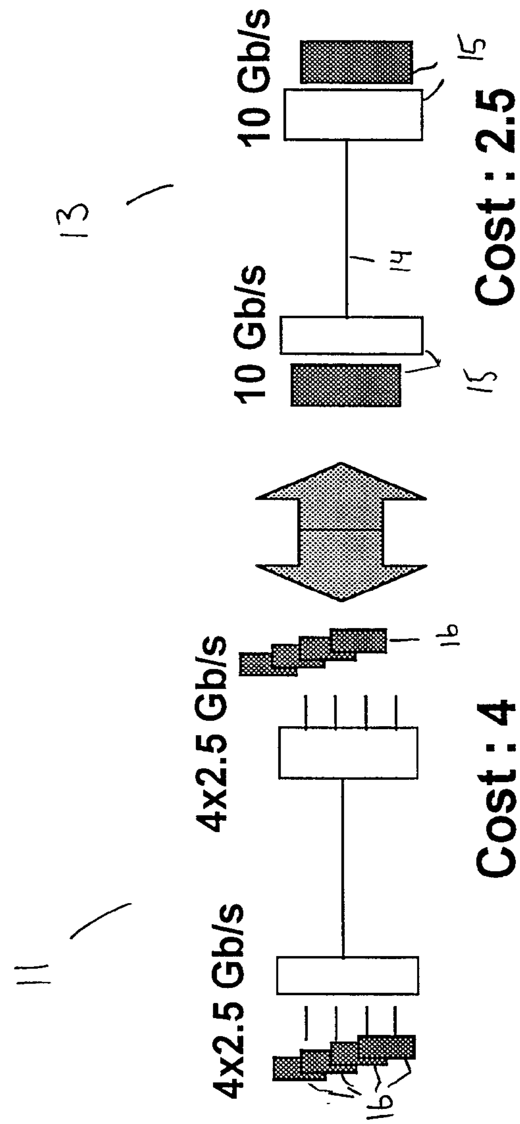


Fig. 1

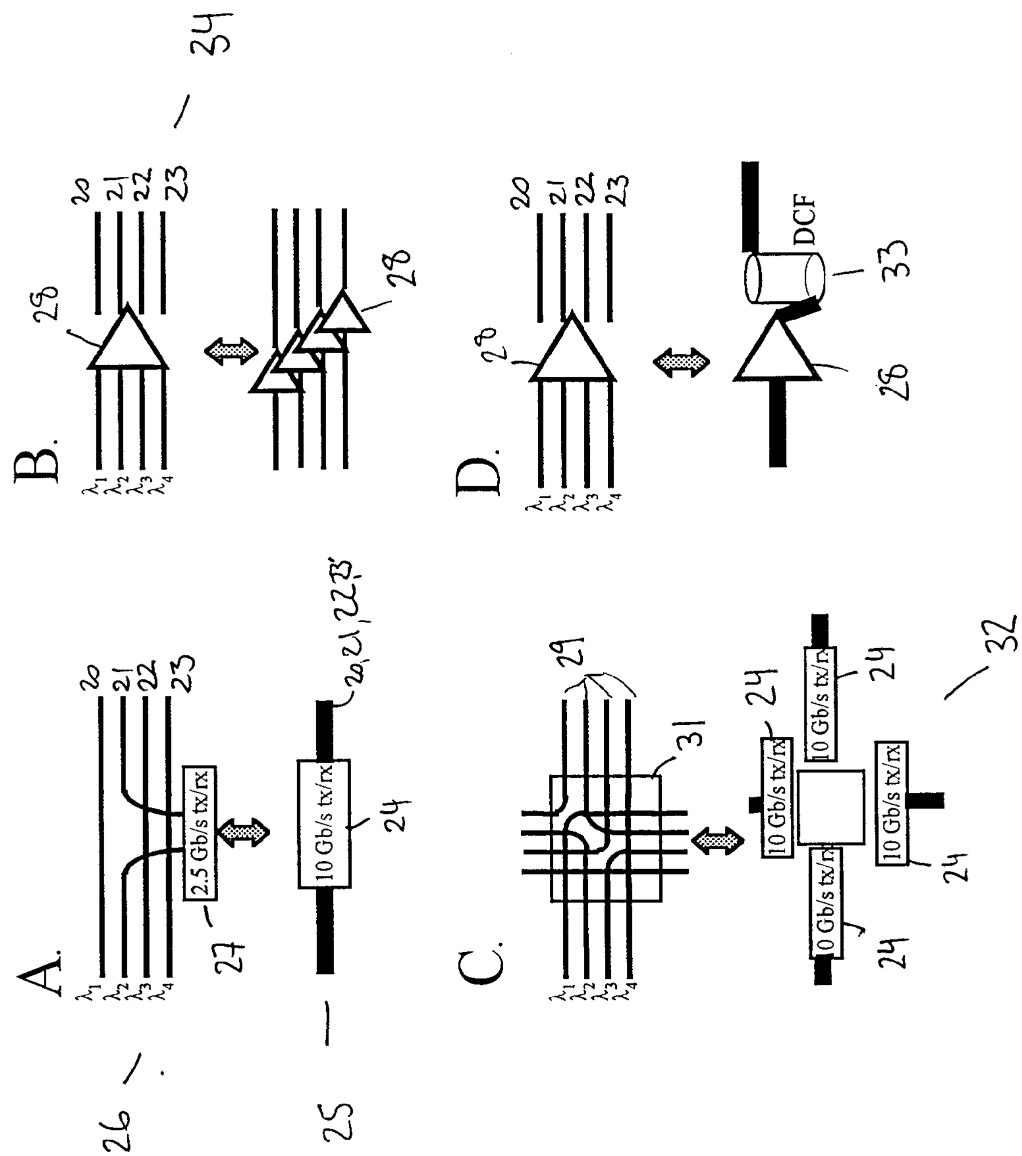
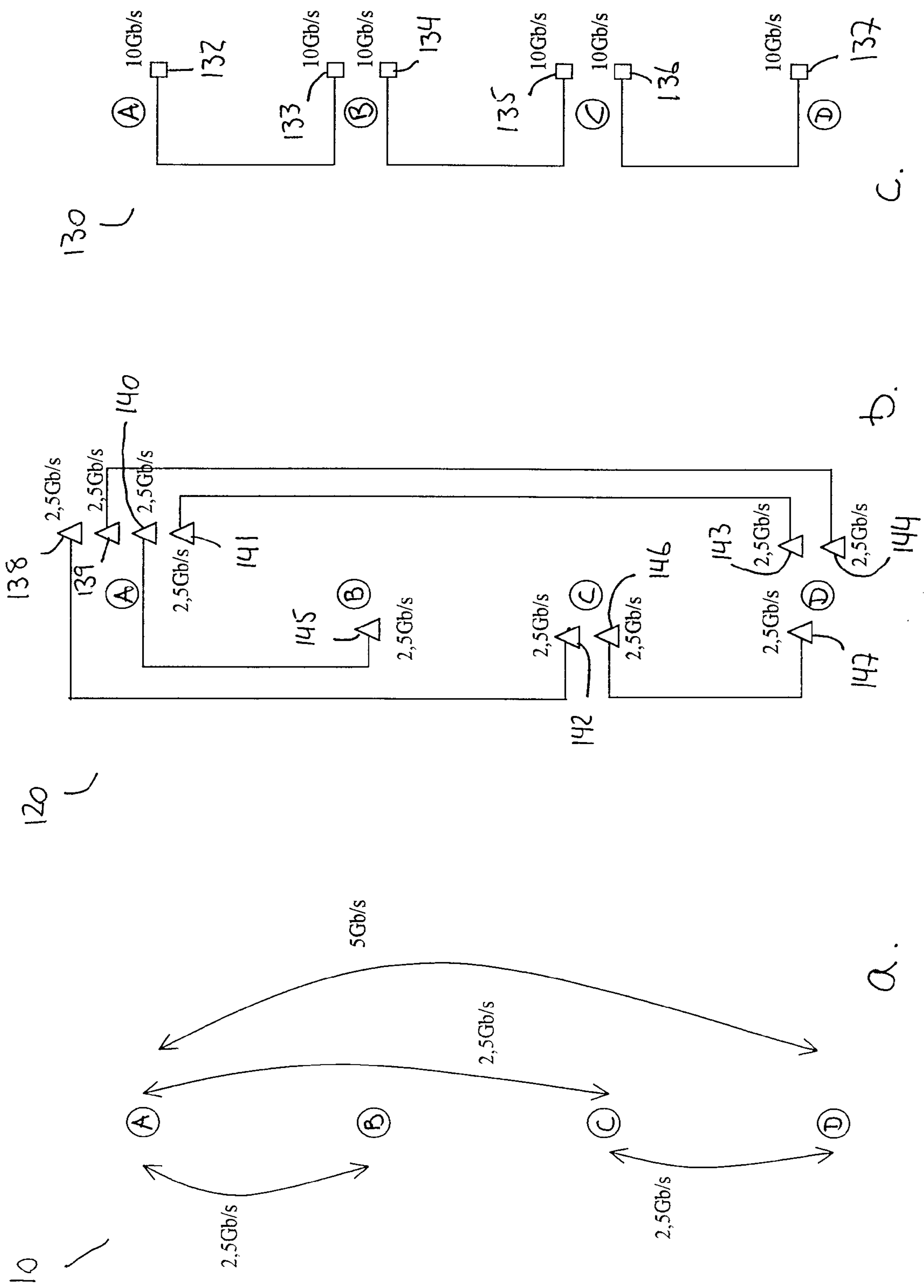


Fig. 2



130
A
B
C
D
10Gb/s
132
133
134
135
136
137
c.
120
138
139
140
141
142
143
144
145
146
147
2,5Gb/s
b.
110
5Gb/s
2,5Gb/s
a.

Fig. 3

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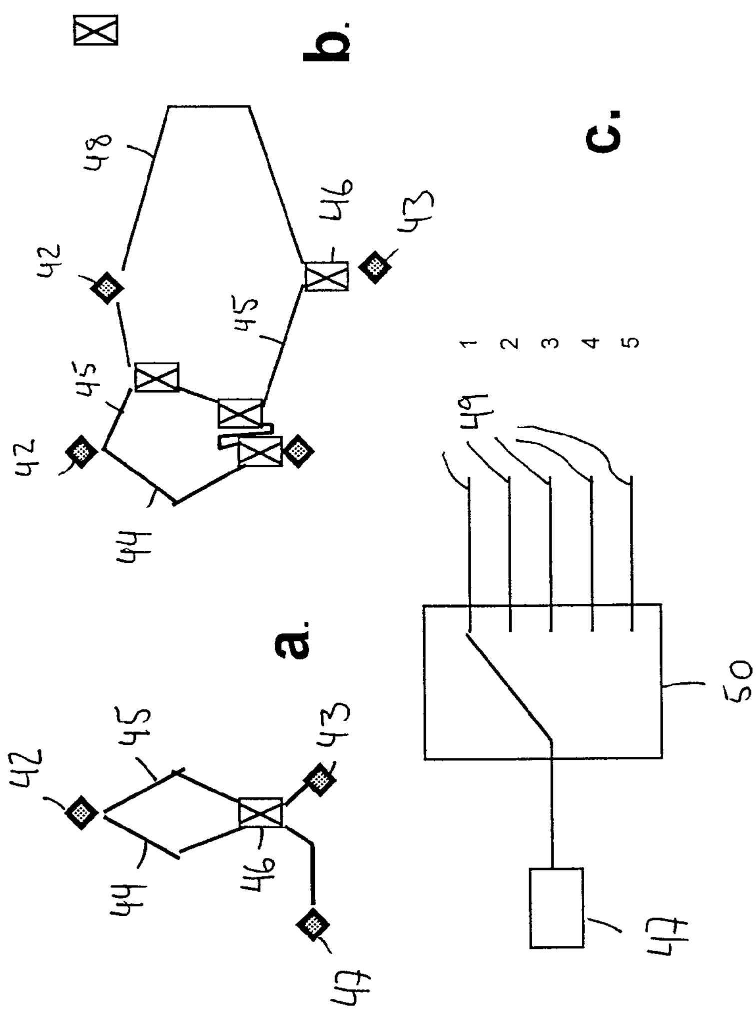

Fig. 4

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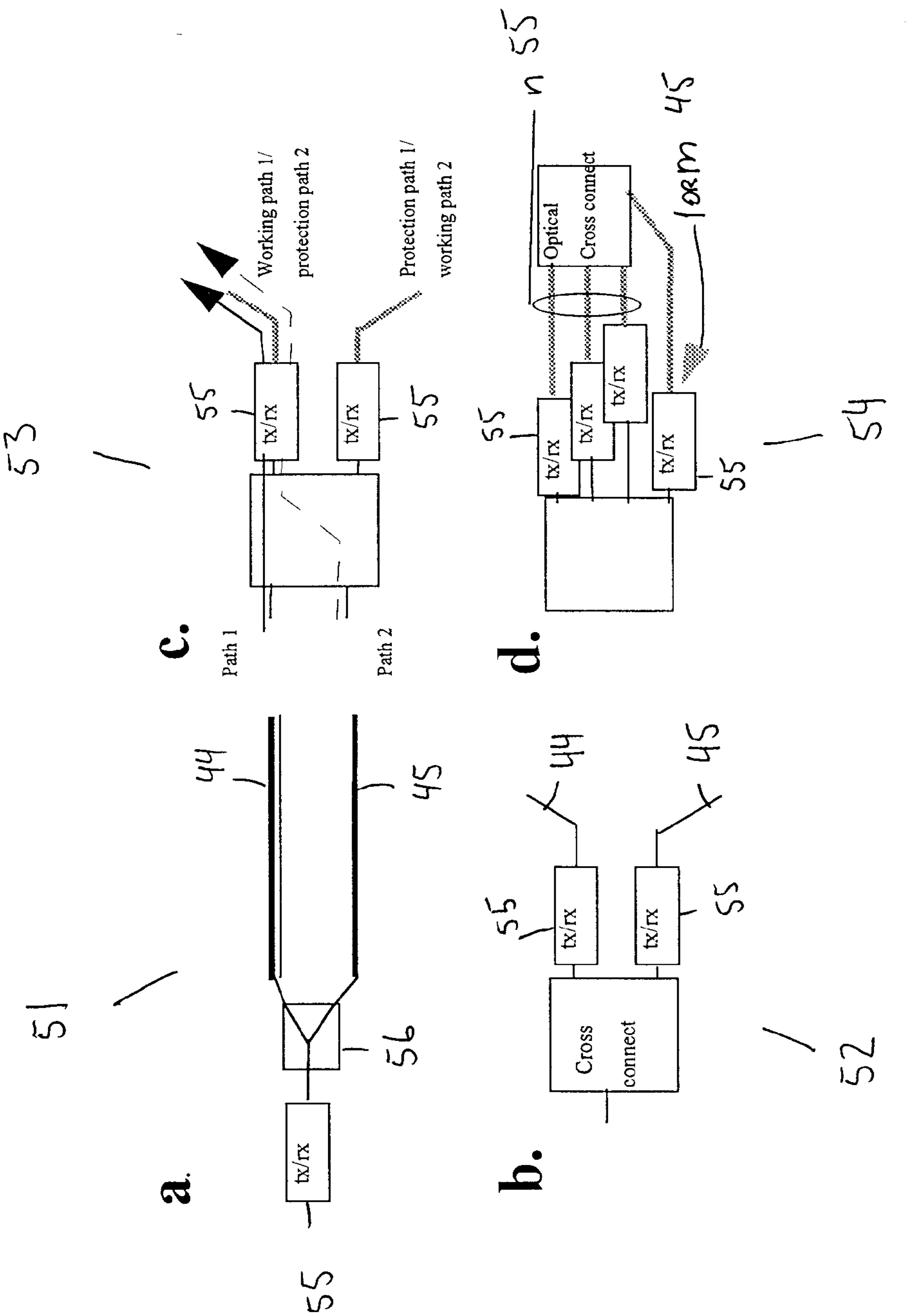
a.
tx/rx
55
56
51
44
45
b.
Cross connect
tx/rx
tx/rx
55
55
44
45
52
c.
Path 1
Path 2
tx/rx
tx/rx
55
55
Working path 1/ protection path 2
Protection path 1/ working path 2
53
d.
tx/rx
tx/rx
tx/rx
tx/rx
Optical Cross connect
n 55
45
10km
55
55
54

Fig. 5

Type Optical network	Transmit-ter protected	Extra cost, C_{prot} (WDM network)
a.	No	1 (+ low-cost optical switch <0.05)
b.	Yes	2
c.	Yes	2^{1+Kt} (+ electrical XC)
d.	Yes	$\approx 1+m/n$ (in n:m protection, + OXC)
TDM		Extra cost, C_{prot} (TDM network)
MSSPring	Yes	$\approx 2^{1+Kt}$
Restoration	Yes	$\approx (1+1/d)^{1+Kt}$
1+1,1:1	Yes	2

Fig. 6

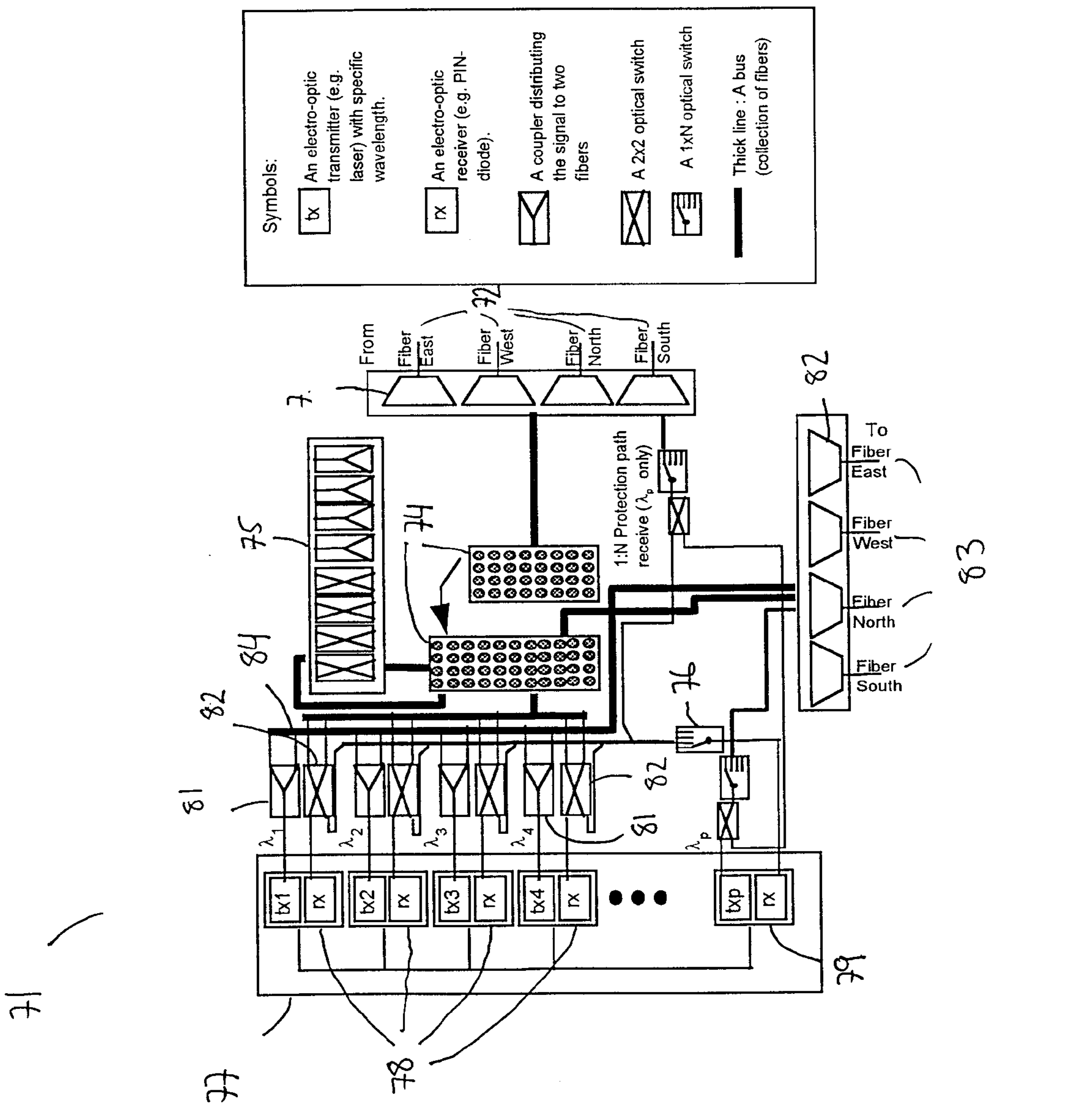
Symbols:
tx
An electro-optic transmitter (e.g. laser) with specific wavelength.
rx
An electro-optic receiver (e.g. PIN-diode).
A coupler distributing the signal to two fibers
A 2x2 optical switch
A 1xN optical switch
Thick line : A bus (collection of fibers)
From
Fiber East
Fiber West
Fiber North
Fiber South
72
75
74
84
82
76
1:N Protection path receive (λ_p only)
To
Fiber East
Fiber West
Fiber North
Fiber South
82
83
81
82
81
λ_1
λ_2
λ_3
λ_4
λ_p
tx1
rx
tx2
rx
tx3
rx
tx4
rx
txp
rx
79
71
77
78

Fig. 7

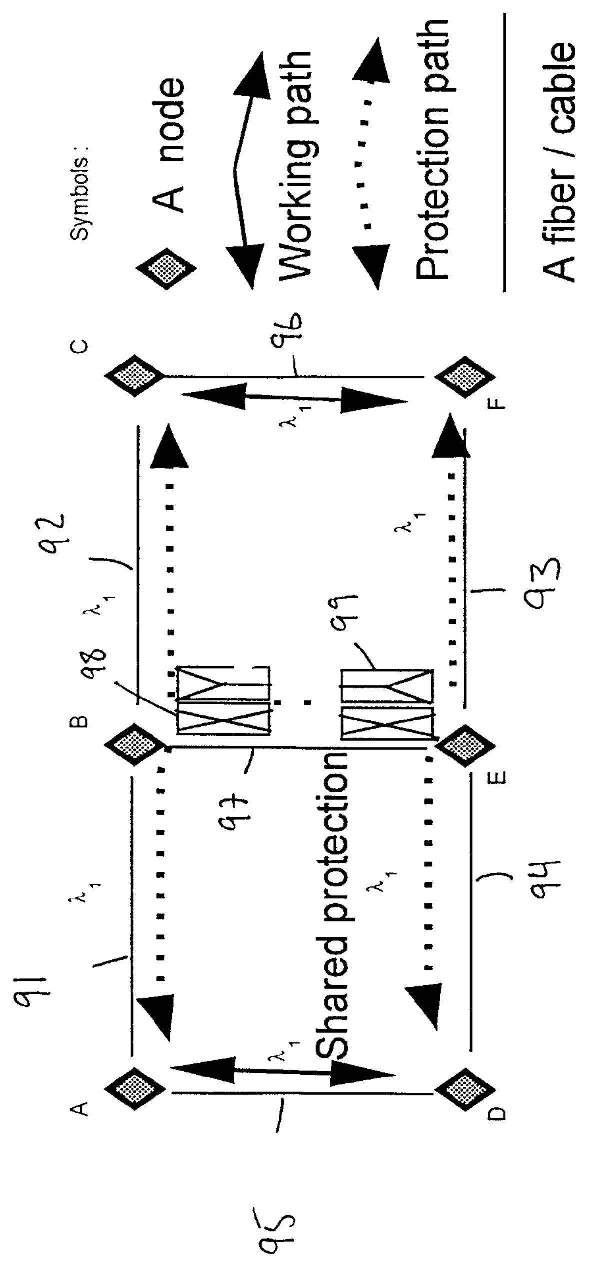
Symbols :
A node
Working path
Protection path
A fiber / cable
A
B
C
D
E
F
Shared protection
λ_1
91
92
93
94
95
96
97
98
99

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 98/00428

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B10/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 559 622 A (HUBER MANFRED ET AL) 24 September 1996 see abstract; claims 1,2; figure 1	1-4
Y	US 4 878 726 A (FATEHI MOHAMMAD T) 7 November 1989 see abstract; figures 6,7	1-3
A	see column 4, line 33 - line 61	4
Y	US 5 113 276 A (PASCHER HELMUT) 12 May 1992	4
A	see abstract; claims 1,3,6; figures 2-4	1,3
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 183 (E-1348), 9 April 1993 & JP 04 334135 A (NEC CORP), 20 November 1992 see abstract	1-3

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 January 1999	18/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Goudelis, M

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/DK 98/00428

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		JP 7044498 B	15-05-1995
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